BEHAVIOUR OF ENVIRONMENT BACKGROUND NEUTRONS ON THE ANTARCTIC ICE FIELD (EXTENDED ABSTRACT)

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This short note points out a few properties of atmospheric background neutrons near the ice surface, particularly some practical advantages of measuring spatial distributions of neutrons on the Antarctic ice field.

Since the theoretical studies of BETHE *et al.* (1940), the diffusion problem of atmospheric neutrons produced by cosmic rays has been fairly well solved with progress in experimental research. One of the current problems is the so-called interface effect between air and soil (or air and seawater) near the earth's surface (KASTNER *et al.*, 1970; O'BRIEN *et al.*, 1978). It can be represented by two kinds of spatial distributions of neutrons as a function of neutron energy, with respect to altitude and zenith angle. The former was investigated experimentally on slow neutrons (KODAMA *et al.*, 1980), and the latter was measured on fast neutrons (PRESZLER *et al.*, 1974, 1976). Most of these works were carried out in the vicinity of the ground surface, because experimental exploration is rather easy on the air-ground interface, but are not always practical on the air-seawater interface. Since the influence of an ice field on the diffusion and absorption mechanisms of neutrons is considered equivalent to that of seawater, experiments on the Antarctic ice field can give some basic and important knowledge to solve the air-water interface problem, on which experimental data are quite poor.

Let us consider first the zenith angle dependence of neutrons. PRESZLER *et al.* (1974) pointed out that the upward neutron fluxes are about half of the downward fluxes in the energy range from 10 to 100 MeV. However, information on such ground albedo neutrons is not available at all for the slow and thermal energy regions, in which the recoil proton method of determining the incident direction of a neutron does not work.

In the present work, evidence of ground albedo neutrons in the energy range less than 1 MeV was obtained from simultaneous measurements of neutrons above and below a variable amount of snow cover. In the measurement at Takada three sets of BF_3 neutron counters, each of which was covered by a 2 cm-thick polyethylene moderator, were used. The detection efficiency of this moderated type of neutron counter is almost constant for neutron energies of less than about 1 MeV (YAMASHITA *et al.*, 1966). They were installed a) 3 m above the ground, b) on the ground level, and c) 20 cm under the ground, respectively. After several snow-

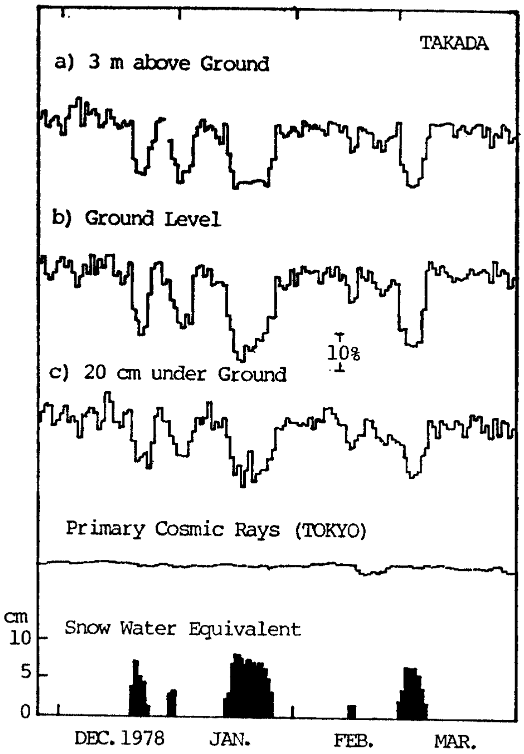

Fig. 1. Day-to-day variations of atmospheric neutron fluxes, snow water equivalent depth and primary cosmic ray intensity. The former two were observed at Takada. Three sensors for neutron measurements were set a) 3 m above the ground, b) on the ground, and c) 20 cm under the ground, respectively. Snow water equivalent depths were determined by snow samplings. Primary cosmic rays are recordings of the NM-64 neutrons monitor in Tokyo, demonstrating a negligibly small amount of change in relation to atmospheric neutrons.

falls of which the water equivalent depth was on the order of 10 cm during a winter season, all of the three counters simultaneously recorded significant decreases of neutron fluxes, as clearly seen in Fig. 1. As both counters b) and c) are situated always under the snow cover, it is reasonable that a certain degree of neutron absorption by the snow cover is expected (KODAMA, 1980). Since counter a) is held high enough above the snow surface throughout the winter season, it is interpreted that the observed flux decreases are due to the snow absorption of the ground albedo neutrons. From a quantitative comparison with recordings of the counter b), the albedo neutron flux in the 1 MeV or less energy range is estimated to be about 45% of the total flux. This value is found to be on the same order of magnitude as that for the 10–100 MeV energy range. However, both of these results were obtained on a ground surface. It is open to question how the amounts of albedo neutrons are distributed on a ice surface.

Next, we proceed to the altitude dependence of neutrons. According to the helicopter experiment of KODAMA *et al.* (1980), the standard attenuation length of 145 g/cm^2 of fast neutrons in air abruptly decreases at about 400 m height above the ground (or seawater) surface, being 70 and 50 g/cm^2 over land and seawater, respectively. Near the bottom of the atmosphere, the equilibrium condition of atmospheric neutrons with their parent cosmic ray nucleonic components no longer holds, so that the production, moderation and absorption behaviour of neutrons is different in air and soil (or air and water). This situation should lead us to an abnormal change of the attenuation length, particularly a marked rise of thermal neutron fluxes near the interface (O'BRIEN *et al.*, 1978).

One of the Japanese Antarctic scientific stations, Mizuho, has two advantages in the course of atmospheric neutron study. As Mizuho Station is located at 2230 m elevation, neutron fluxes are expected to be about five times sea level fluxes, resulting in better counting statistics. Moreover, a 30 m-high meteorological observation tower is available for measuring the altitude distribution of neutrons over the ice surface. Of course, it is of importance to measure the depth dependence of neutrons under the ice surface, in order to be able to match boundary conditions at the air-ice interface.

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